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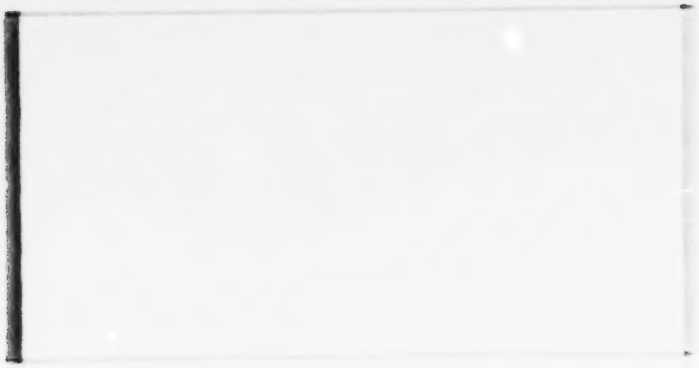

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CORROSION AND TRITIUM TECHNOLOGY SECTION 1985 REVIEW AND 1986 PROGRAMS

Report 86-48-K

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ABSTRACT

The projects and achievements of the Corrosion and Tritium Technology Section during 1985 are reviewed. Proposed projects and objectives for 1986 are outlined and an overview of the changes in direction of the work of the section is presented.

job	file	date	report no.
740682-801-081	827.0	March 12, 1986	86-48-K

TABLE OF CONTENTS

		Page
1.0	INTRODUCTION	1
2.0	SECTION GOALS AND FUNCTIONS	1
3.0	STAFF AND MAJOR AREAS OF ACTIVITY	2
4.0	MAJOR CLIENT GROUPS	5
5.0	1985 RESEARCH PROGRAMS	6
5.1	Power Plant Corrosion Unit	6
	(a) Zr Corrosion Programs	6
	- PT Corrosion Model	6
	- FOCUS	6
	- Morphological Analysis of ZrO_2 on P/T Materials	7
	- PHTS Materials - Corrosion by AP Decontamination	8
	- Effect of PT Surface Condition	8
	(b) Thermal Plant Programs	9
	- Erosion-Corrosion of Feedwater Heaters, Nanticoke TGS	9
	- Superheater/Reheater Exfoliation	10
	- Boiler Tube Analysis	10
	(d) Plasma/Ceramics Programs	10
	- The State-of-the-Art on Energy Use in Production of Engineering Ceramics	10
	- An Assessment of the Energy Use in the Traditional Ceramic Industries in Canada	11
	- Assistance in the Development of a Plasma Laboratory at Lakeview TGS	11

TABLE OF CONTENTS (Cont'd)

	Page
- Thermal Plasma Activity (with Electrical Research)	11
(e) Other Corrosion Studies	11
- 1985 Corrosion Inspection at the Mothballed BHWP-D	12
- 1985 Corrosion Inspection BNGS 'A' Intake Structure	12
- Bellhole Investigation of Bruce NGS 'A' 16" Low Pressure Service Water Pipe	12
- Miscellaneous Small Corrosion Studies	13
5.2 Tritium Technology Unit	14
(a) TIS Programs	14
- Tritium Removal Facility (TRF) - Tritium Immobilization System (TIS)	14
(b) Fusion/Tritium Research Programs	14
- Permeation Program	15
- Getters for Temporary Tritium Storage	15
- Getters for Glovebox Atmosphere Detritiation	15
- Tritium Applications Program	16
- Reactor Exhaust Treatment	16
- Tritium Loop Design	16
- Tritium Laboratory Development	17

TABLE OF CONTENTS (Cont'd)

		Page
5.3	Nuclear HX and Nuclear Waste Container Corrosion Unit	17
	(a) Steam Generator Corrosion Programs	17
	- Effects on Tubing and Corrosion Consequences of Water Jetting of the Tubesheet Sludge Pile	17
	- Chemical Cleaning Corrosion Testing	18
	- Stress Corrosion Cracking of Steam Generator Tubing Alloys	19
	- Evaluations of Tubes Removed from Service	19
	(b) Heat Exchanger Corrosion Programs	20
	- Laboratory Electrochemical Testing, Pit Propagation Rates	20
	- Laboratory Immersion Testing, Isothermal and Non-Isothermal	21
	- Test Rig I, for PNGS Installation	21
	- Test Rig II, for DNGS Installation	22
	- Fundamental Studies, Effects of Alloy Composition	22
	(c) Turbine Rotor Programs	22
	(d) Waste Container Corrosion	23
	(e) Pitting Corrosion of Primary Heat Transport System Materials	23
	- Pitting of Primary Heating Transport System	23
	(f) Other Projects	24
	- Preparation of Stress Corrosion Cracks in 304L Stainless Steel Pipe	24
	- Corrosion Testing of Tool Steels Decontamination Reagent	24

TABLE OF CONTENTS (Cont'd)

		Page
6.0	1986 RESEARCH PROGRAMS	25
6.1	Power Plant Corrosion Unit	25
	(a) Zr Corrosion Programs	25
	- PT Corrosion Modelling	25
	- FOCUS	25
	- Carrier Fuel Bundles - Phase II	26
	- Morphology of ZrO_2 on Pressure Tube Materials	26
	- Influence of PT Material/Environment on Corrosion	27
	(b) Thermal Plant Programs	27
	- Boiler Tube Analysis	27
	- Treatment to Prevent Exfoliation of Tube Bores	27
	- Erosion-Corrosion of Feedwater Heater Tubing	28
	(c) Plasma/Ceramics Programs	28
	- Assessment of Energy Use in the Traditional Ceramic Industries	28
	- Thermal Plasma Laboratory Activities	28
	- Lakeview Plasma Facility Development	28
	(d) Other Corrosion	28
	- 1986 Corrosion Inspection at the Mothballed BHWP-D	28
	- 1986 Corrosion Inspection BNGS 'A' Intake Structure	29
	- Bruce 'B' and Pickering 'B' GS Buried Emergency Water System Piping - Corrosion Risk	29
	- Underwater Concentric Neutral Cable Corrosion	29
	- Testing Program - Cables BNGS Roof Seal Assembly	29

TABLE OF CONTENTS (Cont'd)

		Page
	- Corrosion of Metals in Coal Ash - A Field Study	29
	- Cathodic Protection for BHWP Water Systems	30
	- Nanticoke GS - Cathodic Protection of Underwater Boiler Blowdown Piping	30
	- Small Corrosion Analysis Requests	30
6.2	Tritium Technology Unit	30
	(a) TIS Programs	30
	- Tritium Removal Facility (TRF) - Tritium Immobilization System (TIS)	30
	(b) Fusion/Tritium Research Programs	31
	- Permeation Program	31
	- Getter Program	31
	- Tritium System Development, Tritium Technology Applications	32
6.3	Nuclear HX and Nuclear Waste Container Corrosion Unit	32
	(a) Steam Generator Corrosion Programs	32
	- Effects of Tubing and Corrosion Consequences of Water Jetting of the Tubesheet Sludge Pile	32
	- Chemical Cleaning Corrosion Testing	33
	- Stress Corrosion Cracking of Steam Generator Tubing Alloys	33
	- Evaluations of Tubes Removed from Service	33
	- Corrosion Consequences of Debris Damage in PNGS Unit 3, Boiler 5	34
	(b) Heat Exchanger Corrosion Programs	34
	- Laboratory Electrochemical Testing	34
	- Laboratory Immersion Testing	34

TABLE OF CONTENTS (Cont'd)

		Page
	- Test Rig I	34
	- Test Rig II	35
	- Fundamental Studies	35
	(c) Turbine Rotor Disc Stress Corrosion Cracking	35
	(d) Waste Container Corrosion	36
	(e) Pitting Corrosion of the Primary Heat Transport System Materials	36
	- Pit Growth Studies	36
	- Localized Corrosion in Decontamination Solutions	36
7.0	OVERVIEW	37
8.0	PRESENTATIONS AND PUBLICATIONS - 1985	39

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To
Mr. F.J. Kee
Director of Research

CORROSION AND TRITIUM TECHNOLOGY SECTION 1985 REVIEW AND 1986 PROGRAMS

1.0 INTRODUCTION

Before reviewing the major accomplishments of the Corrosion and Tritium Technology Section during 1985, the current organization of the section will be briefly outlined. The last issue of a year end report of this kind was in February of 1984 for the 1983 Review and 1984 program and the section was then called, Corrosion and Thermal Plant. Since that time, the section has seen significant growth in the Tritium Technology area and has been reorganized to accommodate this growth, principally by breaking off the Thermal Plant Unit and combining it with the new Materials Integrity Section. Hence, the renaming of the section as Corrosion and Tritium Technology. The section goals and functions have been re-written to reflect the new consolidated program responsibilities and there have been some necessary staff changes and reorganization of resources to respond to both new and intensified program initiatives in these areas.

Most of the section's work continued to fall into three broad program areas: Nuclear Generation, Nuclear Waste Disposal, and Thermal and Hydraulic Generation. As well, some new work has developed in the Utilization and Alternate Energy Systems program area. This basic mix of work is expected to continue in 1986. After reviewing the 1985 work accomplishments, the major work packages planned to be undertaken this year will be summarized. Finally, a prediction as to the most probable direction of the section's future activities and initiatives in the medium and longer term, will be presented.

2.0 SECTION GOALS AND FUNCTIONS

Goals

The goals of the section may be summarized as follows:

- To provide a resource of specialized test facilities and advanced knowledge in various and specialized aspects of corrosion science, corrosion engineering, and metal/hydrogen isotope interactions.

- To carry out pure and applied research in these areas, together with supplying consultative, investigative and testing services to other units of the Corporation.

Functions

The section is organized to ensure that its expertise and resources may be used to:

- Assist in design of processes and systems to maximize efficiency of electricity production and transmission.

- Help maintain and/or improve process and system reliability.

- Help maximize component and system operating life.

- Forecast and plan for future demands for service including the area of lateral business opportunities.

3.0 STAFF AND MAJOR AREAS OF ACTIVITY

In order to manage the day-to-day activities of a large section with an unusually heavy work load during 1985, I have as an interim measure, operationally divided the section's work programs among three work units, as described below. Additional consolidation of an effective organizational structure along these lines, will be established during 1986.

As a result of the recent pressure tube failure at Pickering (ie, fracture of G16 in 1983), and the direct influence of corrosion on this failure, there has been a pressing demand for increased capability and resources in Unit 1 - the Power Plant Corrosion Unit. This has been addressed by the addition of Dr. S.R. Lukac in 1984 as a temporary employee, and the hiring of Dr. B.D. Warr from Technical and Training Services (in May 1985) to bolster the priority area of Zr alloy corrosion. Unfortunately, equally high priority in Unit 2 - Tritium Technology, to design, build and deliver a Tritium Immobilization System (TIS) by early 1986, to the Darlington Tritium Removal Facility (TRF), has necessitated temporarily assigning Dr. P. Mayer (from the Power Plant Corrosion Unit to Project Manager) to manage this key activity during much of 1985 and until full completion in 1986. The loss of the extensive experience/capability of Dr. P. Mayer has required us to concentrate only on the highest priorities in the Zr corrosion area and contract out some work until this unit is able to resume a normal work schedule and re-acquire a full compliment of resources. R. Reesor worked throughout 1984 and 1985 in the Power Plant Corrosion Unit as a contract professional staff member to

respond to a new initiative which may have potential lateral business opportunities. The work has involved assessment of electrical load growth associated with traditional and engineering ceramics manufacturing in Ontario.

During 1985, the TIS project entered the critical fabrication stage resulting in very large staff increases for Unit 2. R. Jones was hired as a technician for a one year period, and Mr. G. Till, on loan from the Chemical Research Department, continued to work full time on the project. The project subsequently added 6 additional AECL technicians subcontracted to work on one of the TIS gloveboxes at AECL-SPEL, 4 summer students, a total of 3 temporary draftsmen, and a total of 8 engineering staff from, various Head Office departments, and AECL-CO, again on a temporary basis. This was an absolute requirement in order to maintain the critical Darlington schedules. The regular staff in Unit 2 was strained even further with the loss of Dr. W.T. Shmayda, on attachment to TEXTOR in Julich, Germany for 6 months, responsibilities for helping in the design, committment, planning and initiation of a new Tritium Laboratory Facility and high priority work in support of Canadian Fusion Fuel Technology Program (CFFTP) lateral business initiatives. These demands have been further met by the addition of R. Opatril, hired as a temporary technician and the conversion of N.P. Kherani's temporary contract to a regular staff position and his assignment full time to this work area.

Dr. B.D. Warr was temporarily assigned to work in Unit 3 during 1984 in place of P.J. King who took a development rotation in CNS (TTSD). With the return of P.J. King in May 1985, his responsibilities resumed, and as previously noted, Dr. Warr was subsequently hired for assignment to Unit 1.

The current day-to-day operating organization of the section is, therefore, as follows, also noting that Dr. P.C. Lichtenberger took over in January 1985 as Section Head to fill the vacancy left by Dr. J. Brown, who had earlier been promoted to Manager of the Metallurgical Research Department.

Power Plant Corrosion (Unit #1)

Unit Head - Corrosion:	Dr. P.	Mayer*
Engineers:	Dr. A.V.	Manolescu
	Dr. B.D.	Warr
	Dr. S.R.	Lukac
	Mr. R.A.	Reesor
Technologists:	Mr. A.C.	Headon
	Mr. J.W.	Mummenhoff
Technicians:	Mr. E.M.	Rasile

*Temporarily assigned to Unit #2 in June 1985 as Project Manager, TIS.

- Carry out pure and applied research into corrosion behaviour of metallic construction materials used in the generation and transmission of power, and in the production of heavy water in order to solve existing and anticipate future problems.

- Develop and maintain specialist and advanced capability in the Zr alloy corrosion field to solve existing and anticipate future problems.

- Develop and test materials processes and measures for protection of structures and equipment against metal wastage due to corrosion.

- Provide failure analysis service and consultation on corrosion related problems to the Corporation.

Tritium Technology (Unit #2)

Project Manager - TIS:	Dr. P. Mayer
Engineers:	Dr. W.T. Shmayda
	Mr. J.O. Noga
	Mr. A.G. Heics
	Mr. N.P. Kherani
Technologists:	Mr. K.D. Geiger
	Mr. B.L. Fishbein
Technicians:	Mr. M.J. Dudycz
	Mr. G. Till
	Mr. R. Opatril
	Mr. M. Jones

- Carry out pure and applied research into metal/hydrogen isotope interactions in support of the Tritium Removal Facility (TRF).

- Maintain and operate an active Tritium Laboratory in support of corporate research programs, and provide failure analysis service and consultation on tritium related problems.

- Provide a resource to undertake research and to act as a consultant to the Canadian Fusion Fuels Technology Project (CFFTP).

Nuclear Heat Exchanger and Secondary Side Corrosion (Unit #3)

Engineers: Mr. P.J. King
Mr. K.W. Lam

Technicians: Mr. S.W. Borda
Mr. L. Chee
Mr. L. Grant
Ms. B. Guest

- Carry out pure and applied research into the corrosion of Nuclear Heat Exchanger (HX) tubing (including Steam Generators) support structure and associated components under operating and fault-water conditions.

- Carry out pure and applied research into the corrosion properties of possible container materials for the underground disposal of irradiated nuclear fuel.

- Develop, evaluate, and apply electrochemical corrosion monitoring techniques for corrosion research.

- Provide failure analysis service and consultation on related corrosion problems to the Corporation.

4.0 MAJOR CLIENT GROUPS

D&D - Design and Development Division
CFFTP - Canadian Fusion Fuels Technology Project
NGD - Nuclear Generation Division
THGD - Thermal and Hyraulic Generation Division
TTSD - Technical and Training Services Division
CEA - Canadian Electrical Association
LNL - London Nuclear Limited
MDD - Market Development Division
NBVD - New Business Ventures Division
DSD - Distribution Systems Division

In the sections that follow under 1985 review, and 1986 programs, cross-references to major work program areas, and identification of principle investigators, and major client groups appear in brackets as follows:

(Major Clients; Major Work Program Area; Principle Investigator)

5.0 1985 RESEARCH PROGRAMS

5.1 POWER PLANT CORROSION UNIT

(a) Zr Corrosion Programs

The major objective of research programs in the area of Pressure Tube (PT) corrosion is to predict corrosion and hence Deuterium (D) levels in reactor PTs. This is an important corporate objective since the size of PT blisters arising from possible PT-Calandria Tube contact, can be directly related to D levels in the PT. A secondary objective of our corrosion program is to develop and evaluate practical techniques such as chemical inhibitors or Chromium plating to minimize corrosion and D pick-up.

- PT Corrosion Model

Work on modelling of PT corrosion in early 1985 began with the setting up of a data base containing all available numerical data, such as oxide thickness and D levels, for removed CANDU PTs. A methodology was established in conjunction with the Operations Research Department, to analyze the data and construct a model for Zr-2.5 wt % Nb (Zr-2.5 Nb) PT corosion. The dependence of corrosion on variables such as Fuel Channel temperature and flux was evaluated. Corrosion rate was found to increase with temperature. The increase was modelled by means of an Arrhenius-type exponential law. Flux variances along the channel length appeared to have only a moderate effect on corrosion rate.

Using the corrosion model, short-term predictions of maximum uniform oxide thickness in Pickering 3 and 4 Zr-2.5 Nb PTs were made. By the year 1990, average uniform oxide thicknesses of 20.5 microns are predicted. There is a 95% confidence level that average oxide thickness will not exceed 30 microns by 1990, although locally thick regions of oxide may exceed these predictions. The predictions were based on a small amount of data from only two PTs from Pickering 3 (J09) and Pickering 4(N16). The model will be refined as further data becomes available from PT in-situ inspections, examinations of removed PTs, and experimental programs.

Also during the year, contacts were established with other research institutions such as AECL-CRNL and U of T, with the ultimate goal of developing joint research programs, as well as providing more professional interaction.

(D&D/TTSD; Nuclear Generation; B.D. Warr/S.R. Lukac)

- FOCUS

In the past, corrosion and deuteriding of pressure tubes in CANDU reactors have resulted in costly unscheduled outages (eg, Pickering G-16).

Corrosion of pressure tubes depends on the type of material, operating time, temperature, water chemistry, oxide thickness, dissolved oxygen in coolant and neutron flux. Based on out- and in-reactor experience with Zr-2 pressure tubes, corrosion rate appears to accelerate when oxides reach 15 to 20 μm in thickness. Experience with Zr-2.5 Nb corrosion in short term tests in lithiated water indicates that this material behaves differently. Although some limited data (principally from selected PTs removed from CANDU reactors after up to 12 years) exists, the long term kinetic behaviour (both typical and extremes of behaviour) of Zr-2.5 Nb in- and out-reactor cannot be reliably predicted.

To generate well controlled and statistically meaningful reference base line out-reactor corrosion data, the FOCUS program (Fuel Channel Out-Reactor Corrosion Under Simulated Conditions) was defined and initiated in November 1984 and scheduled for continuation until 1996. The objective of this program is to establish long term out-reactor corrosion and H_2 pick-up data for PT materials in order to provide a data base to assist in the development of the PT corrosion model and computer code for in-reactor performance predictions. The program consists of the following two phases:

Long term tests, up to 10 years, are being carried out in static and refreshed autoclaves to determine the pre-transition, transitory and post-transition corrosion kinetics of Zr-2.5 Nb in simulated CANDU high temperature lithiated water (pH >10.2). Relationships between corrosion advancement and hydrogen pick-up and time, temperature (250-300°), and H_2/O_2 (ppm/ppm) ratio will be established.

Accelerated tests, with preoxidized Zr-2.5 Nb samples (up to 30 μm thick oxide) will be carried out in static and refreshed autoclaves to characterize the post-transition corrosion and hydrogen pick-up kinetics.

During 1985, the static and refreshed autoclaves were refurbished and conditioned. The pickling and autoclaving procedures for Zr-2.5 Nb alloy were selected and the samples required for static autoclave tests prepared. The first two tests, in static autoclaves (250 and 270°C), were initiated.

(D&D/TTSD; Nuclear Generation; A.V. Manolescu)

- Morphological Analysis of ZrO_2 on P/T Materials

To investigate the morphological characteristics of in-reactor and out-reactor formed oxide scales on Zr-2.5 Nb pressure tubes resulting from contact with PHT coolant, a program was initiated in 1985. The results of this analysis are required as input to: the development of the PT corrosion model and the sample design definition for in-reactor carrier bundle tests using pre-oxidized coupons. Based on this analysis, it is anticipated that the best method of preparation of pre-

oxidized samples for the FOCUS program simulating the in-reactor scales will be selected. To achieve this objective, the following method of approach was chosen:

(i) Pre-oxidize PT materials in steam at 400-500°C and high pH LiOH to produce 10-30 μm thick, post-transition ZrO_2.

(ii) Select and prepare samples from PTs removed from Pickering NGS Units 3 and 4 from areas of thick oxides and high hydrogen concentration.

(iii) Perform morphological and structural analysis of both out-reactor and in-reactor oxides.

During 1985, the analysis of oxide scales on pressure tubes removed from Pickering NGS, Units 2, 3 and 4 by optical and scanning electron microscopy was completed. The oxide scales grown in LiOH solutions of different concentrations were analyzed. Comparison of in-reactor and out-reactor scales is in progress.

(D&D; Nuclear Generation; A.V. Manolescu)

- PHTS Materials - Corrosion by AP Decontamination

A program to determine the corrosion effect of combined Dilute Alkaline Permanganate (AP) and CANDECON decontamination solutions on selected components of the Primary Heat Transport System of CANDU reactors was carried out. The purpose of the AP decontamination solution is to remove chromium-containing compounds from indigeneous and deposited oxide scales.

To achieve this objective, general and galvanic corrosion tests were carried out. The results of the investigation showed that both AP and CANDECON solutions have a deleterious effect only on malcomized 17-4 PH material; this material is vulnerable to general corrosion and to galvanic corrosion when coupled with a more noble material.

(TTSD; Nuclear Generation; A.V. Manolescu/A.C. Headon)

- Effect of PT Surface Condition

The objective of this joint program (with AECL) in 1985 was to establish the effects of fret marks in PTs from Pickering 8, on long term corrosion and hydriding behaviour. This information was urgently required by the client (D&D) in order to provide evidence to the AECB regarding the integrity of PTs in this unit. Various samples from previously removed tubes were exposed in static autoclaves (260°C, pH 10 and 12.5 for 1 and 2 week periods). Each sample contained damaged and undamaged surfaces with a range of defect depths from approximately 100 - 500 microns. Samples were examined visually and with electron/optical microscopy both before and after exposure.

Fretted regions appeared to show local areas of accelerated corrosion in conditions approaching that expected in service (260°C and pH 10). Under the same conditions, a thin discontinuous oxide film was observed in fretted regions, which may have been the beginning of the formation of a protective oxide layer. Regions of the exposed PTs which were covered with the original autoclaved oxide remained unchanged following all test exposures.

Results were reported to the client as they arose. Full reporting is scheduled for 1986. Further long-term studies are planned as part of the FOCUS program.

(D&D; Nuclear Generation; B.D. Warr/S.R. Lukac)

(b) Thermal Plant Programs

- Erosion-Corrosion of Feedwater Heaters, Nanticoke TGS

Admiralty brass tubed 4th point low pressure feedwater heaters from Nanticoke TGS have experienced a large number of failures. A work program, consisting of metallographic analysis of failed tubes, laboratory tests and station feedwater chemistry monitoring, initiated in 1984 in collaboration with CTS, was completed. The objective of this program was to establish the root cause of the failures and recommend ameliorative measures. The findings of metallographic investigation of failed tubes indicated that the tubes failed due to a flow assisted localized corrosion process of electrochemical nature initiated from the internal tube surface exposed to feedwater.

The laboratory tests showed evidence of galvanic effects due to electrochemical cell formation between bare Admiralty brass areas and areas covered with scales and deposits. The exact cause of local variations in surface condition resulting in discrete bare unpredicted surface areas has not been established but could be related to inherent differences in surface texture and microstructure following thermal mechanical fabrication processing. The feedwater monitoring program showed that the increase in copper transport products was most likely caused by the effect of decomposition products of morpholine added for feedwater pH control. Based on these findings, the recommendation to change from morpholine to ammonia for pH control was implemented in 1985 in all units at Nanticoke TGS.

Metallographic investigation of 4th point feedwater heater tubes removed from Units No 6, 5, 2 and 4 at Nanticoke TGS was carried out to estimate the extent of corrosion-erosion damage. The results showed that all investigated tubes experienced erosion-corrosion damage during operation.

To evaluate chemical treatments of internal surface of the tubes and/or feedwater so that practical methods are established to prevent further damage of feedwater heater tubes, a corrosion loop has been designed for installation at Nanticoke TGS. Tests will begin in 1986.

(TTSD; Thermal Generation; A.V. Manolescu)

- Superheater/Reheater Exfoliation

Exfoliation of scales which form on the internal surface of superheater and reheater tubes may lead to severe erosion damage in turbines as the oxide particles contained in the steam are highly abrasive. One of the solutions to this problem is to inhibit scale growth by the chemical treatment of the steamside scale to facilitate plastic flow in it and block mass transport through the oxide scale. Development of such a chemical treatment is the objective of this program funded by the Canadian Electrical Association (CEA). Excellent progress was made in this program; several boron containing formulations were identified and thoroughly tested in the laboratory. The best candidate chemical treatments were then used to treat sections of reheater tubes at Lambton TGS for long term testing. In October 1985, treated and untreated tube sections were removed from the reheater of Unit 1 after two years of operation. The metallographic examination of steamside scale to estimate the extent of scale growth and exfoliation on both treated and untreated samples is currently in progress.

(CEA/TTSD; Thermal Generation; A.V. Manolescu)

- Boiler Tube Analysis

At the request of Central Thermal Services (CTS), a number of waterside scale analyses were performed on boiler tubes removed from Nanticoke TGS and Lakeview TGS. The objective of these analyses was to characterize the morphology of the scales and deposits and to evaluate the extent of waterside corrosion before (so as to plan effective cleaning procedures) and after acid cleaning of the units (to confirm the effectiveness of such procedures).

(TTSD; Thermal Generation; A.V. Manolescu)

(d) Plasma/Ceramics Programs

- The State-of-the-Art on Energy Use in Production of Engineering Ceramics

A study for CEA in energy utilization in production of engineering ceramics was completed in July 1985. This work has assessed the state-of-the-art in engineering ceramics and their possible impact on future electrical load. The conclusions which can be drawn from the

crack of minimum detectable length should be considered present at first startup and following every inspection which indicates no detectable cracks. This is an ongoing project.

(TTSD; Nuclear Generation; S.W.Borda)

(d) Waste Container Corrosion

Evaluation of copper's suitability as a container material for the ultimate disposal of irradiated nuclear fuel continued in 1985.

Immersion tests with durations of up to approximately a year on the effects of sulphide on copper's corrosion behaviour have been completed. Some tested coupons are still being examined.

Testing on the effects of radiolysis on the corrosion of copper is in progress. These tests are being conducted in the Auxiliary Irradiated Fuel Bay at Pickering NGS. Two stainless steel cylinders containing autoclave systems were placed on the bottom of the bay next to the irradiated fuel modules. Copper coupons are embedded in simulated geologic environments in the autoclaves. The corrosion rates of the copper coupons are being monitored periodically by polarization resistance. The tests have been running for five months and will last for approximately a year.

(D&D; Nuclear Waste Disposal; K.W. Lam)

(e) Pitting Corrosion of Primary Heat Transport System (PHTS) Materials

- Pitting in Primary Heat Transport System

This project was initiated in 1985 to assess whether pits in PNGS Units 1 and 2 feeders and endfittings will propagate during subsequent operation and to determine whether other system materials may have been similarly pitted during decontamination. The project consists of three parts: a literature survey of high temperature pitting and expert consultation, a short term autoclave test to obtain preliminary pit growth rates, and electrochemical and immersion tests to investigate pitting of various alloys in decontamination solutions.

The literature survey and expert consultation supported the initial judgement that pits are unlikely to grow under normal primary heat transport (PHT) conditions (pH 10 LiOH, <20 ppb oxygen, 300°C). The view that dynamic flow, galvanic effects, and chemical impurities are important factors to be addressed was also supported. In addition, the possibility of other consequences of the existing pits were raised. Pits may act as initiation sites for stress corrosion or corrosion fatigue cracking. Corrosion fatigue cracking is of greater concern; however, the probability of either is very small.

Autoclave immersion testing has been started. Actual field specimens and samples of feeder and endfitting materials containing artificial pits are being exposed to PHT conditions. The test exposures are not yet complete.

Cyclic potentiodynamic polarization and immersion tests were performed on a range of alloys in decontamination solutions. Intergranular attack of alloy 400 and alloy 600 was observed, as was pitting of bronze and alloy 17-4 pH. Although these tests were carried out under abnormal conditions, it is possible that these materials are pitted at PNGS Units 1 and 2. However, the conditions under which this localized attack could occur and the roles of individual components of the decontamination solution on that attack are as yet to be investigated.

(TTSD; Nuclear Generation; K.W. Lam)

(f) Other Projects

- Preparation of Stress Corrosion Cracks in 304L Stainless Steel Pipe

A short project was undertaken to produce cracks in a pipe section to be used as an ultrasonic inspection test piece. Cracks were successfully produced by a 150 hour exposure to a boiling $MgCl_2$ solution.

(TTSD; Nuclear Generation; L. Grant)

- Corrosion Testing of Tool Steels in Decontamination Reagent

A short program of immersion testing was undertaken to determine the general corrosion rates of A2 and D2 grade tool steels under PNGS-U3 decontamination conditions. The corrosion rates, determined from 48 hr test exposures were found to be variable, but within the range of 0.02 μ m/hr to 0.28 μ m/hr.

(TTSD; Nuclear Generation; B. Guest)

findings indicate that a significant requirement on electrical load (up to 1200 MW) could occur if engineering ceramics compete with metallic materials in the future.

(CEA/MDD; Utilization & Alternate Energy Systems; R. Reesor/P. Mayer)

- An Assessment of the Energy Use in the Traditional Ceramic Industries in Canada

This study is designed to review present process technologies in the traditional ceramic field and identify opportunities for productivity and efficiency improvements especially by utilizing electro-technologies. The study was initiated in September 1985 and is scheduled for completion in April 1986. This project is co-funded by CEA and Ontario Hydro, Market Development Division and Research Division.

(CEA/MDD; Utilization & Alternate Energy Systems; R. Reesor/P. Mayer)

- Assistance in the Development of a Plasma Laboratory at Lakeview TGS

This project has involved providing engineering assistance in the design and construction of a plasma arc laboratory at the OHRD facility at Lakeview TGS. The auxiliary systems (water and gas) for the plasma torch are being installed. The power supply has been tested and the electrical connections to the torch and instrumentation panel have been completed. The laboratory should be commissioned in February 1986 for use by external clients.

(OHRD/MDD/NBVD; Utilization & Alternate Energy Systems;
R. Reesor/P. Mayer)

- Thermal Plasma Activity (with Electrical Research)

Several powder processing projects for external clients were carried out in 1985. Fine high purity nickel powder was processed in the plasma torch at OHRD to obtain a high purity, fine NiO powder by the high temperature oxidizing process. Problems with the feeding and collection system have so far precluded adequate oxidation.

A fine alumina powder is being processed in the plasma laboratory to spheroidize the particles in an attempt to make the powder more sinterable (higher density and surface reactivity). These tests will continue in 1986.

(OHRD/MDD/MVBD; Utilization & Alternate Energy Systems,
R. Reesor/P. Mayer)

(e) Other Corrosion Studies

- 1985 Corrosion Inspection at the Mothballed BHWP-D

The third annual corrosion inspection of the mothballed BHWP-D was completed. The assembled metallic components of Enriching Units 7 and 8 and the Vacuum Degassing Unit were examined.

The domes of E7 towers A, B, C and 2nd stage have corroded under deteriorated mastic and wet insulation. Tower B dome was to be stripped of wet insulation and mastic and coated during the summer to control this corrosion. It was recommended that the other domes be treated in the same way.

The large motor control valves in E7 are now showing active crevice corrosion between the bonnet and the valve body. It was recommended that the crevices be cleaned and sealed with an industrial caulking compound.

(D&D; Nuclear Generation; A.C. Headon)

- 1985 Corrosion Inspection BNGS 'A' Intake Structure

The 1985 corrosion survey consisted of the following:

1. An underwater potential survey to check the operation of the sacrificial anodes protecting the highly stressed areas of the structure.

2. Removal of 2 year and 3 year exposure coupons for examination and corrosion rate calculation.

3. In service visual inspection of the structure.

It was found that the cathodic protection system was operating satisfactorily. The average corrosion rates for the general corrosion coupons for 2 years and 3 years was 0.03 mm/y. The average corrosion rate for the cathodic protection coupons was 0.01 mm/y. The visual inspection indicated that no rapid deterioriation of any component was occurring.

(Nuclear Generation; A.C. Headon)

- Bellhole Investigation of Bruce NGS 'A' 16" Low Pressure Service Water Pipe

A visual inspection was made of a 16" low pressure service water pipe at Bruce NGS 'A' to estimate the rate of corrosion of the underground piping. It was found that a sacrificial anode cathodic protection system installed with the pipe was not providing protection. The protective coating was flaking off in some areas. The maximum pit

depth found was 0.9 mm. The corrosion rate for the outer surface of the pipe was estimated to be 0.1 mm/y. No further corrosion protection was recommended.

(D&D; Nuclear Generation; A.C. Headon)

- Miscellaneous Small Corrosion Studies

Numerous short term tests were conducted or consultation provided on underground, aqueous and atmospheric corrosion problem, such as:

- Galvanic Corrosion in the Low Pressure Service Water System (NGD; Nuclear Generation; A.C. Headon)

- Possible Corrosion of 304 Stainless Steel Expansion Joint Seal Plates by Halogens; Darlington GS 'A' (D&D; Nuclear Generation; A.C. Headon)

- Bruce NGS A Vacuum Building Inspection Requirements (1987 Outage), D&D Report No 86008 (D&D; Nuclear Generation; A.C. Headon)

- Rehabilitation of the Cathodic Protection System of the Post-Tensional Anchors at Kipling GS (THGD; Thermal and Hydraulic Generation; A.C. Headon)

- Bellhole Investigation of Buried Water Pipes at NPD NGS Rolphton (NGD; Nuclear Generation; A.C. Headon)

- Underwater Concentric Neutral Cable Corrosion (DSD; Utilization and Alternate Energy Systems; A.C. Headon)

- Examination of a #2 ACSR Sample of a Neutral-8F2 Feeder, Herridge Lake DS (DSD; Utilization and Alternate Energy Sytems; A.C. Headon)

- Aluminum Conductor Parting at Beachville Line (DSD; Utilization and Alternate Energy Systems; A.C. Headon)

- Long Term Storage of D_2O in 304SS Gallon Drums at BHWP-F4 (NGD; Nuclear Generation; A.C. Headon)

- Preparation of Stress Corrosion Cracks in 304SS Pipe (TTSD; Nuclear Generation; L. Grant)

- Corrosion Testing of Tool Studs in Decontamination Reagent (TTSD; Nuclear Generation; B. Guest)

5.2 TRITIUM TECHNOLOGY UNIT

(a) TIS Programs

- Tritium Removal Facility (TRF) -
  Tritium Immobilization System (TIS)

Tritium exposure of the CANDU operating and maintenance personnel contributes significantly to the yearly radiation dose. In an effort to reduce this occupational hazard, Ontario Hydro is constructing TRF at Darlington NGS. The purpose of this facility is to remove tritium from the primary heat transport coolant and moderator. The TIS is a part of this facility and its function is to immobilize the concentrated gaseous tritium separated by the cryogenic distillation. This is achieved by reacting this gas with an active metal (titanium) to form a solid product (tritide) in a container for storage or sale.

The process of tritium immobiliation on metals was conceived and developed at Ontario Hydro Research Division. This work served as a basis for the TIS design.

The detailed design of the TIS which was performed by OHRD and is now completed, included: preparation of design descriptions, design requirements and a process flow diagram based on preliminary design, development of quality verification plans and procedures, design and layout of gloveboxes, airlocks, process lines and equipment, glovebox atmosphere and process gas monitors and analyzers, process instrumentation and control, electrical power distribution, preparation of specifications and equipment selection.

The fabrication of the TIS is managed by Ontario Hydro Research Division. This work, which is currently in an advanced stage of completion, is performed by OHRD personnel. Due to the extent of this project, it was necessary to engage AECL-SPEL to assist with engineering and fabrication to meet the delivery date of the TIS. The fabrication of the TIS, which began in September 1985, includes equipment and material procurement, construction and assembly of all components, quality verification inspection and testing, engineering support of fabrication, and preparation of testing, commissioning and operating manuals.

(D&D; P. Mayer/J.O. Noga/A.G. Heics)

(b) Fusion/Tritium Research Programs

Research activity has centered on hydrogen isotope interactions with materials. Both protium and deuterium have been used in a variety of investigations. Where feasible, tritium operations have been simulated by spiking one of the two lighter isotopes with helium. The goal has been to develop a data base amenable to tritium handling for systems currently planned or under construction at Ontario Hydro and for fusion reactors. The main thrusts of this year's activities can be subdivided into four categories: permeation through metals, getter

assessment for temporary storage and for feedstock purification, laboratory investigations in support of the tritium application's program and the design and construction of the tritium laboratory and its tritium delivery system. R. Opatril, B. Fishbein, K. Geiger, N.P. Kherani and W.T. Shmayda have been involved to varying degrees in each of the four areas.

- Permeation Program

This work is a continuation of a program initiated in 1983. The key results are: extension of the theory of permeation through metals to include composite layers, identification of the operating conditions where permeation in the forward direction differs from that in the reverse direction, experimental confirmation of these predictions and identification of possible applications of this phenomena. Two applications are: pumping tritium gas at low pressures and tritium - helium separation. A pump based on this concept has been patented. A permeation probe has been built, installed on the tokamak TEXTOR (Torus Experiment for Technology Oriented Research) and used to measure the radial atomic hydrogen fluxes to the vessel wall. The device represents a new diagnostic for tokamaks.

(CFFTP; Nuclear Generation; W.T. Shmayda)

- Getters for Temporary Tritium Storage

Investigations in the application of getters to tritium handling systems have been underway since January 1983. Work to date has predominately focussed on temporary storage of tritium by using uranium powder. Fundamental studies on the kinetics of bed performance have lead to the design, construction and testing of two beds: one containing 15 grams of uranium and the other containing 660 grams. In parallel, the performance of a 6 kg bed built by Los Alamos National Laboratories-Tritium Systems Test Assembly (TSTA) and a 100 gram bed built by Amersham Corporation have been tested. In the past year, two beds have been designed for tritium service: one contains 25 grams of uranium and the other containing 3 kilograms. These beds feature low heat loss to the surroundings under operating conditions and secondary containment to minimize tritium permeant losses to the environment.

(D&D/CFFTP; Nuclear Generation; W.T. Shmayda)

- Getters for Glovebox Atmosphere Detritiation

The feasibility of using a zirconium/iron (ST198) alloy to remove tritium from a typical glovebox atmosphere is under study. A loop has been constructed and installed in a glovebox at the Tritium Systems Test Assembly (TSTA) in Los Alamos. Preliminary tests at concentrations ranging from 10 to 1000 mCi/m^3 indicate that tritium can be scrubbed out of a nitrogen atmosphere even in the presence of impuri-

ties such as carbon dioxide and methane. These tests indicate that the rate of tritium removal from the nitrogen atmosphere can be increased by minimizing stagnant zones with the flow loop.

(CFFTP; Nuclear Generation; W.T. Shmayda)

- Tritium Applications Program

This R&D program, initiated early in 1984, was instituted at OHRD to confirm some of the Tritium Immobilization System (TIS) operations and to provide the D&D design team with an experimental data base in tritium gas handling prior to the design of the tritium applications program (TAP) loop. TAP will be installed at the Tritium Removal Facility at Darlington NGS. The key results of this work are: confirmation of batch loading of titanium sponge at 1/4 of full scale, measurement of the Immobilization Tritium Container (ITC) unloading dependence on temperature, loop configuration, hydrogen to metal ratio, and helium content in the feedstock, identification of the optimal recovery temperature for unloading ITC's, identification of viable loop configurations for gas transfers from ITC to uranium beds, establishment of ITC cover gas removal procedures and measurement of the temperature excursions of valves nearest to the ITC during an unloading operation. This latter result has lead to the elimination of the all heat exchangers in the TAP and TIS loops.

(D&D; Nuclear Generation; W.T. Shmayda)

- Reactor Exhaust Treatment

The burn up fraction of fuel (a 50% deuterium, 50% tritium mixture) in a tokamak is expected to be very low. As a consequence, the unreacted fuel needs to be returned to the torus a number of times. "Helium ash" and any impurities generated in the torus or by plasma wall interactions (water, methane, tritiated water, tritiated methane and so on), dilute fuel mixture and enhance radiative power losses from the plasma. They must be removed from the feedstock prior to its return to the torus. The feasibility of scrubbing these impurities from the fuel stream at typical reactor operating exhaust pressures is under study in this research project. To date, a loop capable of processing exhaust throughputs typical of TEXTOR and JET (Joint European Torus) has been designed and is under construction. Many of the key components are in-house and have been commissioned. First measurements are expected in the first quarter of 1986.

(CFFTP; Nuclear Generation; W.T. Shmayda)

- Tritium Loop Design

Three tritium handling systems have been designed during this year: a 10 curie ultrahigh vacuum system for the University of Toronto (U of T), a 10 kilocurie high pressure pellet charging facility for the University of Rochester (U of R) and a 1200 curie storage and delivery system (TSDS) for the Tritium Laboratory under construction at OHRD.

The U of T system and its supporting laboratory is currently under construction. The preliminary engineering for the U of R system has been completed by D&D and the proposal is under evaluation by U of R personnel. A full scale plastic model of the OHRD TSDS has been constructed to determine the detailed loop configuration and its interaction with the loop's glovebox. The key components are in various stages of being specified, quoted on or ordered.

(CFFTP/OHRD; Nuclear Generation, W.T. Shmayda)

- Tritium Laboratory Development

Construction on the tritium laboratory shell is underway. The outside masonry is expected to be completed early in February. Subsequently, both electrical and mechanical work will proceed. Lab construction is currently on schedule and is expected to be completed towards the end of April. Laboratory equipment is being purchased. Design, specification and purchase of components for the tritium supply and delivery system are in progress.

(OHRD; Nuclear Generation; W.T. Shmayda)

5.3 NUCLEAR HEAT EXCHANGER AND NUCLEAR WASTE CONTAINER CORROSION UNIT

(a) Steam Generator Corrosion Programs

The steam generator corrosion program was initiated in the mid-1970s to assess the probability of significant corrosion failures of alloy tubing in Ontario Hydro steam generators and to define the limits of secondary water chemistry for safe operation. This program is closely associated with a program in the Corrosion Chemistry Unit, Chemical Research, to study chemistry conditions in nuclear steam generators. The level of effort in 1985 was limited due to the high priority placed on the heat exchanger corrosion program. All steam generator corrosion projects are ongoing.

- Effects on Tubing and Corrosion Consequences of Water Jetting of the Tubesheet Sludge Pile

This project was initiated in 1985 to evaluate damage to Alloy 400 tubes from a mockup bundle subjected to laboratory water jetting, and to assess the consequences of such damage on the subsequent corrosion performance of the tubing. Water jetting of individual tubes and a mockup alloy 400 tube bundle was performed by the Mechanical Test and Development Section, Mechanical Research. Evaluation of damage involved examination of tube surfaces and cross-sections by optical and electron microscopy. An initial indication of the effects on corrosion susceptibility was obtained by an aggressive screening test. Tubing samples damaged by direct water impingement and entrained particle impingement were subjected to a 60 day autoclave exposure to 33% Lake Ontario Water, and 25 ppb O_2 at pH 9 (autoclave exposure performed by Corrosion Chemistry unit, Chemical Research).

The autoclave testing did not indicate an increased susceptibility to corrosion. Extensive attack was present on all alloy 400 test probes in both damaged and undamaged areas. Thus, water jetting damage, including direct impingement, does not substantially change the corrosion performance of tubing. The test was not designed to identify subtle differences in performance. Direct impingement causes severe surface disruption and wall loss, whereas abrasion damage of alloy 400 caused by jetting of simulated sludge from a mockup bundle was very shallow with almost no net wall loss. For the most part, the original surface was visible under indentations, scratches, and gouges caused by the abrasion. A slightly greater amount of damage was observed for a 6000 psi jet over that for a 3000 psi jet.

Conclusions to be drawn are: (1) Indirect abrasion, even by a 6000 psi jet should not immediately compromise tube integrity, and (2) Tube damage will not result in substantial changes in corrosion performance for surface-ground alloy 400 tubing; however, subtle effects may result. Effects on unground tubing (i.e. mill finished with an oxide on the tube surface) have not been completely evaluated.

(TTSD; Nuclear Generation; P.J.King)

- Chemical Cleaning Corrosion Testing

This project was initiated in 1984 to help provide an assessment of the extent of corrosion resulting from a chemical cleaning operation. The primary task in 1985 was to evaluate the corrosion of welds in carbon steel steam generator internal components, with special emphasis on galvanic effects from an alloy 600 tube bundle. Assistance was provided to the Corrosion Chemistry unit, Chemical Research in the selection and procurement of weld samples, specimen and galvanic couple setup, and test monitoring. Weld samples were examined visually and by optical microscopy before and after a laboratory chemical cleaning trial performed by the Corrosion Chemistry unit. Galvanic currents between weld samples and alloy 600 tube bundle segments were monitored throughout the clean.

The examinations revealed that, as expected, some preferential attack occurred at the carbon steel welds. The extent of attack was variable across the selection of welds exposed. The blowdown header and shroud seam welds appeared to be most susceptible to preferential attack. The contribution of the galvanic couple to the overall attack could not be established from the tests performed. Preferential attack occurred even in some samples not incorporating a galvanic couple. The measured galvanic currents were generally in agreement with expectations; however, instances of reversed current during the 2nd and 3rd copper removal steps were not expected. These could be explained by redissolution of copper that deposited on the alloy 600 during an iron removal step; however, this hypothesis has not been substantiated. Further analysis of the galvanic currents has not been possible.

Conclusions to be reached are: (1) Immediate corrosion resulting from a single chemical clean should not compromise structural integrity, (2) The blowdown header weld is most likely to undergo accelerated attack during a chemical clean, (3) Long term corrosion effects during subsequent operation cannot be estimated at present, and (4) The effects of multiple chemical cleans on structural integrity must be considered, especially for the blowdown header and shroud seam welds.

(TTSD; Nuclear Generation; P.J. King)

- Stress Corrosion Cracking of Steam Generator Tubing Alloys

This project was initiated in 1983 to obtain data on the stress corrosion of tubing alloys 600, 800, and 400 in steam generator environments encountered at Ontario Hydro Nuclear Generating Stations. The influence on cracking susceptibility of secondary side operating temperatures, 255°C to 265°C, and chemical impurities from condenser inleakage are of particular interest. The test program involves exposure of sections of steam generator tubing or alloy rod to the desired environmental conditions in a high temperature, circulating water system. A tensile stress is applied with a constant extension rate test (CERT) machine, or alternatively may be obtained by plastic deformation of the tubing (eg. tube rolling or bending).

Significant progress was made in 1985 in final preparation of two CERT load frames for stressing tube samples. Computer programming was a major part of the work involved in preparing the rest of the test system. Programs were developed for load frame control, test specimen monitoring, tabular and graphic display of data during test operation, and overall test control. Numerous routines were developed for printer and plotter output of test data. Experimental difficulties were encountered in attempting baseline tubing tests in pressurized high temperature water. Welds attaching test sections to fittings developed leaks after a short time of operation, forcing shutdown of testing before any useful results were obtained. Substantial maintenance was performed on a four load-frame CERT testing facility for rod samples. The major task was the rebuilding of the pressurizing/circulating pump, delays resulted from unavailability of repair parts.

(TTSD; Nuclear Generation; P.J. King)

- Evaluations of Tubes Removed from Service

This project was initiated in 1981 to deal with the corrosion assessment of U-bend tube failures at BNGS-A. Only a small amount of work was performed in this project in 1985 due to emphasis on other high priority projects. Activities included participation in the evaluation of a straight tube section removed from PNGS Unit 1, Boiler 3 for monitoring purposes, further analysis & electron microscopy of failed and sacrificial U-bend tubes, initial development of a

coordinating role to deal with future requirements for joint metallurgical and corrosion assessment of tubes removed for monitoring purposes.

The results of the U-bend studies suggest a synergistic corrosion fatigue-stress corrosion cracking mechanism for crack initiation. From the corrosion standpoint, the results of metallurgical investigations of the straight tube sample are very encouraging. However, the examination of only one or two tubes out of thousands does not provide sufficient evidence to state confidently that some localized tube damage has not occurred or will not occur.

(TTSD; Nuclear Generation; P.J. King)

(b) Heat Exchanger Corrosion Programs

The heat exchanger corrosion program was initiated in 1983 to investigate means of minimizing the localized corrosion of alloy 800 tubed moderator heat exchangers. Since that time the program has expanded considerably due to the increasing need for pitting and crevice corrosion information specific to Ontario Hydro's lakewater cooled heat exchangers. Activities in the program in 1985 were in five major project areas as outlined below. Significant effort was expended in this program due to the immediate importance of providing useful corrosion data and continued corrosion failures of heat exchangers, especially at PNGS. All of the heat exchanger corrosion projects are ongoing.

- Laboratory Electrochemical Testing, Pit Propagation Rates

A special electrochemical polarization procedure (the PPR test) was adapted for use in this project so that some insight could be gained into pit propagation behaviour. The heat exchanger tubing alloys 800, 825, and 28 were tested extensively using the modified PPR technique. Also, some simple potentiostatic polarization testing was performed on these alloys to provide combined information on both the initiation and propagation of pitting and crevice attack.

Results indicate rapid initiation and propagation of attack on alloy 800 over a wide range of applied potential. Initiation of attack on both alloy 825 and alloy 28 appears more difficult, although many pits are formed when initiation does occur. Propagation of attack in the latter two alloys has been very slow for the applied potentials and durations examined to date.

(TTSD; Nuclear Generation; P.J. King)

- Laboratory Immersion Testing, Isothermal and Non-Isothermal

Immersion testing is being carried out both at OHRD and at AECL-CRNL to provide laboratory based pitting and crevice corrosion data for natural (i.e. not electrochemically accelerated) exposures. Isothermal testing consists of exposing flat samples fitted with multiple-crevice assemblies to lakewater in a constant temperature water bath. Non-isothermal testing consists of exposing internally heated tube samples to lakewater cooled by a large volume of flowing tap water. Silt is packed around a portion of the tube surface to form initial crevice conditions.

A long term (11 000 hr) isothermal exposure to Lake Ontario water at 40°C was completed in 1985. Initial visual and optical microscope examination revealed no attack on any of the austenitic nickel alloy samples. Some shallow crevice attack was evident on alloy 400 and 70/30 cupronickel samples. Long term (4500 hr) non-isothermal testing of multiple alloy 825 and alloy 28 samples was completed at CRNL. Tube wall temperatures ranged throughout the test from 40°C to 55°C. Three of four alloy 825 samples suffered crevice corrosion; none of the alloy 28 samples showed any signs of localized attack. As in previous tests, attack on alloy 825 was less severe than would be experienced by alloy 800 after comparable exposure.

Conclusions to be drawn from the laboratory testing (both electrochemical and immersion) are: (1) Alloy 825 can be expected to have a useful service life considerably longer than that of alloy 800, (2) Alloy 28 will perform somewhat better than alloy 825 in heat exchanger service, and (3) Neither alloy 825 nor alloy 28 can be specified with confidence of obtaining a 30 yr service life.

(TTSD; Nuclear Generation; P.J. King)

- Test Rig I, for PNGS Installation

This project was initiated in 1983 to obtain corrosion information, especially in the short term (1 month to 1 year), under simulated service conditions employing appropriate heat flux, water velocity, temperature, and cooling water chemistry. A test rig comprising three 14-tube heat exchangers and associated piping, pumps, and an 80 kW heat source was constructed in 1985. Thermal performance was tested and found to meet design expectations. The heat exchangers were designed with short term testing in mind; therefore, tubes are removable on an individual basis. A trailer has been obtained to house the test rig and, through the Metallurgy Section of CNS, a site has been chosen and approved for the installation of the rig at PNGS.

(TTSD/D&D; Nuclear Generation; P.J. King)

- Test Rig II, for DNGS Installation

This project was initiated in 1985 to obtain corrosion information, especially in the longer term (1 year to 5 years), under simulated service conditions. The project is complementary to Test Rig I. Approval was obtained to proceed with this project and a finalized design was arrived at based upon the Test Rig I design and thermal testing. Procurement of components and fabrication of the heat exchangers was initiated and a general program of one to four year exposures was outlined.

(D&D; Nuclear Generation; S.W., Borda)

- Fundamental Studies, Effects of Alloy Composition

This project was initiated in 1985 to investigate the fundamental role of alloy composition on the properties of the passive film formed in lakewater and its relation to pitting in the lakewater environment. Plans were finalized for this study to be undertaken at Massachusetts Institute of Technology, and procurement of necessary equipment and test material was initiated.

(TTSD; Nuclear Generation; P.J. King)

(c) Turbine Rotor Disc Stress Corrosion Cracking

This project was started in 1982 to determine crack growth rates and obtain crack initiation data for LP turbine disc material in simulated turbine environments. The test program involves exposure of test specimens to condensing steam at 4 temperatures ranging from 120°C to 180°C, in 4 vessels connected in series in a closed circuit flow system. Specimens for crack growth are a 2.54 cm (1") thick wedge-open loaded (1T-WOL) design, fatigue precracked and loaded to 60 MPa $\sqrt{m}$. Those for crack initiation are of the 4-point bend (4-pb) type with a double sample arrangement to provide a crevice, and loaded to 90% yield stress.

Test series #2, exposure to PNGS-A feedwater, was completed in May 1985, 13370 hours since test startup. Due to downtime and several system maintenance problems, actual exposure to condensing steam was 6940 hours. Crack growth estimates from this test, from 0.22 μm/hr to 0.40 μm/hr, are in good agreement with those presently used for life estimates (0.10 μm/hr to 0.45 μm/hr). To date, crack initiation has been observed on only one specimen, although at least three were exposed at each temperature. This is indicative of the variability of the crack initiation process.

Conclusions to be reached are that: (1) Presently used crack growth rates are not overly conservative for life estimates and should continue to be used, and (2) Crack initiation must be presumed to occur very early in service life. For purposes of life estimates, a

6.0 1986 RESEARCH PROGRAMS

6.1 POWER PLANT CORROSION UNIT

(a) Zr Corrosion Programs

- PT Corrosion Modelling

The major early committment to the client in 1986 is to complete the data analysis of both Zr2 and Zr-2.5 Nb PTs including additional data from Bruce 2 P12, and Pickering 3 F13. Results of predictions of oxide thickness and bulk PT D levels in Zr-2.5 Nb PTs are to be reported in February 1986. These predictions will contribute to the SLAR assessment.

As more data becomes available, it will be input to the data base. The model and predictions will then be updated based on the new data. Data on PT material and heat transport system chemistry will be input to the data base to help establish the role of these variables in corrosion. Further theoretical work is being considered to develop a model for radiolysis of the coolant as a function of chemistry and oxide thickness. Development of more understanding of the role of radiation in the corrosion process is also anticipated through experimental (carrier bundle) and theoretical studies. Consideration is also being given to analysing fuel performance, particularly as a means of gaining insight into PT corrosion.

Major emphasis will be given to establishing and initiating critical experiments to support this program. Areas for research are still to be defined at this time, although particular consideration is being given to establishing the timing and magnitude of any corrosion rate change in Zr-2.5 Nb. The success of the modelling program depends largely on our ability to predict any change in corrosion rate before it is identified in reactor.

Emphasis will also be placed on stengthening and further developing contacts and joint research programs in other institutions. For example, Professor C. Ward of the University of Toronto has proposed a program of experimental work to evaluate the mechanism of hydrogen uptake in Zr-2.5 Nb. Following discussions with Prof Ward, we may provide some support for this work in 1986.

(D&D/TTSD; Nuclear Generation; B.D. Warr/S.R. Lukac)

- FOCUS

Scheduled activities during 1985 include continuation of long term tests in static autoclaves. Gravimetric, metallographic (optical and scanning electron microscopy) and hydrogen pick-up analyses on corrosion samples removed periodically from autoclaves will also be carried out.

Thick oxide scales (up to 30 μm will be grown on Zr-2.5 Nb materials and accelerated tests will be initiated.

(D&D/TTSD/CANDEV; Nuclear Generation; A.V. Manolescu)

- Carrier Fuel Bundles - Phase II

In CANDU reactors, H_2/D_2 is added to the coolant during operation to avoid increases in corrosion of supress oxygen formation by radiolysis of D_2O in core and hence of heat transport system components.

The existent CANDU specification on dissolved deuterium level in PHT coolant is based on light reactor experience and some work at CRNL. The effect of dissolved deuterium on corrosion and deuteriding of pressure tubes has not been fully quantified for CANDU reactors. Furthermore, if there is boiling in the core, the molecular species are stripped into the steam phase where D_2 is relatively ineffective at suppressing the radiolytically produced oxygen. The radiolytic processes occurring in boiling are unknown and therefore there are no specifications available for dissolved deuterium level in boiling CANDU reactors.

Therefore, a research program is under development with D&D, and CRNL. The objective of this program is to directly establish in operating CANDU reactors the most effective and realistic dissolved deuterium level in PHT coolant to minimize the long term corrosion rate and deuteriding of pressure tubes.

To achieve this objective, preoxidized (0 to 30 μm thick oxide scales) Zr-2.5 Nb coupons will be exposed, in CANDU reactors with naturally occurring chemistry differences (different levels of dissolved deuterium reactor to reactor) in selected non-boiling and boiling channels using carrier fuel bundles. The scheduled activities for 1986 include preparation of preoxidized samples and preparation of carrier fuel bundles for in-core exposure in 1987.

(D&D/TTSD; Nuclear Generation; A.V. Manolescu)

- Morphology of ZrO_2 on Pressure Tube Materials

The program to analyze the morphology of ZrO_2 scales on PT materials will continue in 1986 with the main objective to establish the best method of preparation of preoxidized Zr-2.5 Nb samples required for FOCUS and Carrier Fuel Bundle programs.

To achieve this objective, the scheduled activities for 1986 include characterization of scale porosity and grain size and shape for both in-reactor and out-reactor oxides. SIMS, AES and TEM techniques will be used to determine the characteristics of oxide scale (structure and chemistry (Li and Nb) at both scale/alloy and scale/environment interfaces and throughout the scale. To obtain information related to the effect of radiation on scale morphology, pressure tube samples removed from CANDU reactors may also be exposed in autoclaves at WNRE for

periods of time up to one year. These samples will then be compared with preoxidized samples from FOCUS and Carrier Fuel Bundle Programs.

(D&D/TTSD; Nuclear Generation; A.V. Manolescu)

- Influence of PT Material/Environment on Corrosion

Three main areas for research under consideration for 1986 are:

(i) Evaluating the effects of PT material (including composition, thermomechanical treatment and surface condition) on corrosion rate. Corrosion modelling in 1985 has shown that there is a large scatter of data on oxide thicknesses and D levels between Zr2 PTs in the same unit. Similar trends are expected for ZrNb. This work will assist in identifying PTs with potentially high rates of corrosion and D pick-up, thus improving our predictive capability, particularly our ability to delineate PTs at highest risk in a reactor.

(ii) The effect of O_2 on corrosion in hot water and low quality steam will be studied on pre-filmed samples or on off-cuts of PT of different origin. Establishment of reliable out-of-reactor corrosion kinetics of Zr-2.5 Nb PT is essential for determination of the flux effect on Zr-2.5 Nb PT corrosion.

(iii) Identifying and evaluating practical techniques (such as coatings and surface conditioning) to prevent corrosion or D ingress, or ameliorate their effects. Contacts were established with Harwell (UK) (Dr. M. Bennett) in 1985, and samples of various coatings have been sent for corrosion testing at OHRD. Also, D. Thomson of McMaster University has expressed an interest in using ion implantation techniques for PT surface modification.

(D&D/TTSD; Nuclear Generation; B.D. Warr/S.R. Lukac)

(b) Thermal Plant Programs

- Boiler Tube Analysis

The service failure and boiler tube analysis will be continued as requested by CTS and/or thermal station.

(TTSD; Thermal Generation; A.V. Manolescu)

- Treatment to Prevent Exfoliation of Tube Bores

The analysis of treated and untreated sections removed from Lambton TGS, Unit 2 will continue. A preliminary report will be issued describing the results.

(CEA; Thermal Generation; P. Mayer/A.V. Manolescu)

- Erosion-Corrosion of Feedwater Heater Tubing

Final design, assembly and installation of a corrosion test loop at Nanticoke TGS will be completed in 1986. The tests designed to evaluate long term performance of stainless steel tubing and the effectiveness of tube and/or feedwater treatments will be initiated in the second half of 1986.

(TTSD; Thermal Generation; A.V. Manolescu)

(c) Plasma/Ceramics Programs

- Assessment of Energy Use in the Traditional Ceramic Industries

The Traditional Ceramic Industries Assessment for CEA/MDD will be completed by April 1986.

(OHRD; Utilization & Alternatie Energy Systems; R. Reesor/P. Mayer)

- Thermal Plasma Laboratory Activities

Throughout 1986, assistance will be provided to Ontario industries interested in ceramic powder processing using plasma devices. Many companies have already expressed interests in several areas. There are active interests in the spheroidization of alumina powder, the processing of a homogeneous mixture of alumina and zirconia powders, and production of AlN powder synthesized in a plasma flame.

(OHRD/MDD; Utilization & Alternate Energy Systems, R. Reesor/P. Mayer)

- Lakeview Plasma Facility Development

An on-going program in 1986 will be the development of the material processing capabilities of the Lakeview Plasma Facility. This will involve the design and installation of a powder feeding and collection system. A torch stand and gas vent will also be acquired. The facility design will provide enough flexibility to accommodate a wide variation of programs performed by external clients.

(OHRD/MDD; Utilization & Alternate Energy Systems, R. Reesor/P. Mayer)

(d) Other Corrosion

- 1986 Corrosion Inspection at the Mothballed BHWP-D

The fourth annual corrosion inspection of the mothballed BHWP-D will be undertaken. The assembled metallic components of Enriching Units 7 and 8 and the Vacuum Degassing Unit will be examined. Other metallic components will be examined as requested. A report containing the results of the survey and recommendations to control any ongoing corrosion will be issued.

(BNPD; Nuclear Generation; A.C. Headon)

- 1986 Corrosion Inspection BNGS 'A' Intake Structure

A 2-3 day inspection (survey) of the intake structure will be made in June 1986. It will involve removal/replacement of corrosion coupons, a potential survey and a visual (photographic) inspection.

(BNPD; Nuclear Generation; A.C. Headon)

- Bruce 'B' and Pickering 'B' GS Buried Emergency Water System Piping - Corrosion Risk

The Emergency Water System piping will be inspected to determine the extent of corrosion. Regardless of the results of the inspection, the existing sacrificial anode system should be upgraded to supplement the coating system.

(D&D; Nuclear Generation; A.C. Headon)

- Underwater Concentric Neutral Cable Corrosion

This study of the failure of underwater concentric cables used to supply island cottages in the Muskoka lakes and Lake Temagami started in 1985 will be completed in 1986. The objective of this work is to identify and predict corrosion rates and expected longevities of the armour wire in lakewater.

(D&D; Utilization and Alternate Energy Systems; A.C. Headon/B.D. Warr)

- Testing Program - Cables BNGS Roof Seal Assembly

Bare post tensioning cables protected by grease and plastic pipes have been corroding on the roof seal assemblies. Two coated cables have been selected as possible replacements:

1. Thermally bonded cross-linked polymer.
2. Galvanized steel.

Tests will be conducted to assist in the selection of the best cable, from the point of view of corrosion, to be used in the replacement of the original cables at the 1987 BNGS-'A' shutdown.

(D&D; Nuclear Generation; A.C. Headon)

- Corrosion of Metals in Coal Ash - A Field Study

The coupons of copper, aluminum, stainless steel, galvanized steel and carbon steel that have been exposed for 4.5 years in fly ash, bottom ash and granular 'A' material will be excavated, cleaned and examined for corrosion. Corrosion rates for the various metals will be calculated.

Visits will be made to fly ash disposal areas that have been in use as building sites, parks and for highway construction where buried metals of construction will be excavated to evaluate the corrosion. This corrosion will be compared with the corrosion of the test coupons.

(Thermal and Hydraulic Generation; Thermal Generation; A.C. Headon)

- Cathodic Protection for BHWP Water Systems

The potential benefits of a cathodic protection system to eliminate the corrosion in the BHWP process effluent line and process coolers will be evaluated.

If benefits can be realized, recommendations of the alternative systems available, which would be best suited for each application will follow.

(BNPD; Nuclear Generation; A.C. Headon)

- Nanticoke GS - Cathodic Protection of Underwater Boiler Blowdown Piping

This boiler blowdown piping consists of a mixture of 304L piping and carbon steel beams attached to a reinforced concrete structure. As there are many unknowns in the retrofitting of a cathodic protection system to this mixed system, a field test will be conducted to establish the degree of the protective current needed.

(D&D; Thermal and Hydraulic Generation Division; A.C. Headon)

- Small Corrosion Analysis Requests

Numerous small corrosion analysis requests will be undertaken for various client groups in various work program areas.

6.2 TRITIUM TECHNOLOGY UNIT

(a) TIS Programs

- Tritium Removal Facility (TRF) - Tritium Immobilization System (TIS)

The fabrication of TIS, designed and developed by Ontario Hydro Research, will be completed on April 15, 1986 for delivery to the Darlington TRF. OHRD will provide assistance to Darlington NGS Operations with commissioning of the TIS and any other related support until placed in operation in the middle of 1987.

(D&D; Nuclear Generation; P. Mayer/J.O. Noga/A.G. Heics)

(b) Fusion/Tritium Research Programs

Research activity on the hydrogen isotope interactions with materials is expected to continue along the lines described in Section 5.2. The two main areas of activity will be: the study of permeation through metals and getter assessments for a variety of applications. Portions of these programs are to be collaborative efforts with TEXTOR in Germany, UCLA in California, TSTA in New Mexico, TOKAMAK de Varrennes in Quebec and University of Toronto in Downsview.

- Permeation Program

Three efforts are foreseen in this area: the continued development of the tritium pump, measurements of plasma discharges on TEXTOR and the design, construction and testing of a permeation probe for the Advanced Limiter Test 1. The tritium pump test facility is expected to become operational during the first quarter of 86. Pump performance characteristics for various operating scenarios such as gas pumping, gas purification, tritium scrubbing from a helium stream and isotope separation will be studied.

The permeation probe commissioned on TEXTOR during 85 will continue to operate. TEXTOR personnel will ensure its operational status. Data obtained during discharges will be accessed via a data link and used to study the physics of plasma wall interactions during tokamak discharges and to assess the performance of the membrane characteristics under long term exposures to plasmas. Information gathered during this phase of the program will be directly relevant to the ALT 1 permeation program.

The ALT 1 permeation program is a new addition to the overall permeation program. The probe tests carried out during 85 confirm that the concept of selective removal of hydrogen from the reactor gases with a permeation membrane is feasible. To demonstrate the applicability of the passive purification concept, a permeation membrane will be installed within the throat of the ALT 1 limiter. This work is in the design phase. Construction of the probe assembly is not expected to begin until the last quarter of 86.

(CFFTP; Nuclear Generation; W.T. Shmayda)

- Getter Program

The work in the upcoming year will be a continuation of the 85 programs: development of bulk storage beds for tritium service, assessment of getters for glovebox detritiation and the investigation of getters for reactor exhaust treatment.

Under the bulk storage bed development thrust, two uranium beds designed for tritium service will be tested. A bed built by Oak Ridge National Laboratories will also be tested at the getter evaluation facility at OHRD.

While depleted uranium has many attractive features for tritium service, it is chemically toxic. Furthermore, it tends to decrepitate, spread throughout the process loop and deteriorate component performance which depends on close tolerances for proper operation. Under a D&D contract, alternatives to uranium gettering will be tested.

The reactor exhaust test loop will be commissioned during the first quarter of 86. The key issue to address will be to establish whether impurities should be removed from the exhaust stream prior to storing the bulk of the DT fuel or after. Once this assessment is complete, getters which optimize the loop performance will be selected and tested.

(CFFTP/D&D; Nuclear Generation; W.T. Shmayda)

- Tritium System Development, Tritium Technology Applications

The tritium supply and delivery system and the tritium lab with all its ancillary systems is expected to be constructed and commissioned provided manpower is available for this work. Consulting projects arise during the course of the year. Two series of Tritium Safe Handling Courses are planned for this year.

(OHRD/CFFTP; Nuclear Generation; W.T. Shmayda)

6.3 NUCLEAR HEAT EXHANGER AND NUCLEAR WASTE CONTAINER CORROSION UNIT

(a) Steam Generator Corrosion Programs

- Effects on Tubing and Corrosion Consequences of Water Jetting of the Tubesheet Sludge Pile

Work on this project will continue in 1986 to determine the effects of jetting parameters on the extent of tube abrasion damage. An initial assessment will be made of possible subtle long term corrosion consequences.

Evaluation of alloy 400 tubes from jetting trials performed by the Mechanical Test and Development Section, Mechanical Research, will be accomplished by visual and microscopic examination. Measurements will be made on micrographs of selected areas of abraded tubing to quantify the extent of damage. Possible corrosion consequences will be assessed by tube examinations before and after an autoclave exposure to simulated operating conditions with little or no acceleration. Results obtained will indicate the relationships between jet pressure and surface damage and between jet standoff and surface damage. The autoclave exposure will provide an indication of the amount of damage that can be tolerated before corrosion increases.

(TTSD; Nuclear Generation; P.J. King)

- Chemical Cleaning Corrosion Testing

Only a small amount of work is anticipated on this project in 1986. The emphasis will be on quantifying preferential carbon steel weld corrosion, and determining the contribution of galvanic coupling to an alloy 600 tube bundle section. Assistance will be provided to the Corrosion Chemistry Unit, Chemical Research, as required.

Weld samples with galvanic coupling to various amounts of alloy 600 tubing and with no galvanic coupling will be prepared. After chemical cleaning (to be performed by the Corrosion Chemistry Unit) samples will be examined visually. Cross-section profiles will be obtained and measured to determine the amount of preferential attack. A relationship will be obtained between preferential attack and cathodic area of the galvanic couple. This will be useful in predicting damage expected in an actual chemical clean and in predicting cumulative damage of multiple cleanings.

(TTSD; Nuclear Generation; P.J. King)

- Stress Corrosion Cracking of Steam Generator Tubing Alloys

Substantial work is to be performed in this area in 1986. Testing will proceed on two test loop facilities utilizing both rod and tube samples. The general SCC behaviour of alloy 600 and alloy 800 in 250°C to 270°C steam generator environments is to be determined.

CERT tests at strain rates from $3 \times 10^{-8} s^{-1}$ to $3 \times 10^{-6} s^{-1}$ will be performed on alloy 600 and alloy 800 rod samples in secondary water environments at temperatures of 250°C, 260°C, and 270°C. Alloy 600 tubes will be CERT tested at 250°C and 260°C with a temperature differential of 20°C between the solution inside the tube and the outside tube wall surface. Results from this testing will help provide a basis on which to relate higher temperature SCC data to operating conditions in Ontario Hydro's nuclear steam generators. An initial assessment of the importance of heat flux as a factor in alloy 600 SCC will be possible on completion of the outlined testing.

(TTSD; Nuclear Generation; P.J. King)

- Evaluations of Tubes Removed from Service

Corrosion assessments will be provided as required. The coordinating role is to be developed further to provide more effective service for client groups. An overall assessment of tube condition in Ontario Hydro's steam generators will be formulated based on the results of 1984 & 1985 tube examinations, past failure analyses, and additional tube examinations.

(TTSD; Nuclear Generation; P.J. King)

- Corrosion Consequences of Debris Damage in PNGS Unit 3, Boiler 5

A new project will be started, in cooperation with the Corrosion Chemistry Unit, to assess the corrosion consequences of damage caused to the primary face of a steam generator by impact of loose parts. Only a small amount of work is expected in 1986. Principal tasks will be to assist the Corrosion Chemistry Unit as required with short term autoclave testing of samples with simulated damage and to review available information on alloy 400 SCC. The review will assist in finalizing plans for CERT testing of alloy 400 in 1987.

(D&D; Nuclear Generation; P.J. King)

(b) Heat Exchanger Corrosion Programs

- Laboratory Electrochemical Testing

The objective for 1986 is to develop relationships for pit propagation rates in laboratory exposures for the presently specified alloys 825 and 28. Parameters studied will be electrochemical potential and temperature. Potentiostatic polarization will be performed for a matrix of growth potential-temperature-time combinations. These tests will provide data that, in conjunction with data from other projects, will ultimately be used to develop laboratory-service performance correlations and to predict in-service performance.

(TTSD/D&D; Nuclear Generation; P.J. King)

- Laboratory Immersion Testing

Both isothermal and non-isothermal immersion testing will continue in 1986 to establish the role of heat flux and tube surface temperature on pitting in lakewaters. A series of tests is to be performed for a matrix of wall temperature-heat flux-time combinations. Extent of localized corrosion will be evaluated by visual examination and optical microscopy, and surface film compositions will be determined by Scanning Auger Microprobe analysis. These tests will indicate whether heat flux is a required parameter for future laboratory corrosion testing for heat exchanger tubing. Much of this work will be performed at AECL-CRNL.

(TTSD; Nuclear Generation; P.J. King)

- Test Rig I

Work in 1986 will be aimed at obtaining an initial assessment of biofilm involvement in scaling and deposition (Biological Section, Chemical Research) and determining initial rates of scaling, deposition, and silting (fouling). Test Rig I will be installed at Pickering NGS early in the year. Short term test program exposures of 1 to 6 months will be completed by late fall. The data obtained wil

provide important insight into the environmental factors contributing to underdeposit corrosion. The initiation of localized corrosion may be observed if fouling is very rapid.

(TTSD/D&D; Nuclear Generation; P.J. King)

- Test Rig II

The 1986 goals for the Test Rig II project are to have the system installed and operating successfully, and to have the long term test program underway. Fabrication of the heat exchanger vessels and construction of the supporting system will be the major tasks for the first half of the year. Installation at Darlington NGS is expected in the summer. The test program should commence in the fall.

(D&D; Nuclear Generation; S.W. Borda)

- Fundamental Studies

In 1986, the role of major constituents of nickel alloys on their corrosion behaviour in lakewater is to be determined. A series of 12 alloys with very low impurity levels will be obtained. Electrochemical testing will be performed to determine general corrosion behaviour of these 'pure' alloys in lakewater. Oxide films formed during electrochemical testing will be analyzed with a Scanning Auger Microprobe. The results of these investigations will provide a basis for further work in 1987 which will examine the localised corrosion of the same alloys. This work is being carried out at Massachusets Institute of Technology.

(TTSD; Nuclear Generation; P.J. King)

(c) Turbine Rotor Disc Stress Corrosion Cracking

A new test series will be started in 1986 to investigate the sensitivity of crack growth rates to environmental changes. A one year exposure to condensing steam at temperatures from 120°C to 160°C is planned. The circulating solution will have a caustic concentration in the range of 10%. Principal tasks in 1986 are specimen and test system preparation. The test exposure is to begin mid-year and conclude in 1987. Comparing crack growth rates from this test with those reported in 1985 will indicate the degree of acceleration caused by a more aggressive environment.

(TTSD; Nuclear Generation; S.W. Borda)

(d) Waste Container Corrosion

The 1986 program will be a continuation of the 1985 program. The results from tests on the effects of sulphide ion on the corrosion of copper will be analyzed and evaluated. Experiments on the effects of radiolysis will be completed and a program on the effect of mass transport of solutes on the corrosion of copper will be initiated.

(D&D; Nuclear Waste Disposal; K.W. Lam)

(e) Pitting Corrosion of the Primary Heat Transport System Materials

- Pit Growth Studies

The corrosion implications of pits formed in the primary heat transport system (PHTS) will be examined. Programs will be initiated to investigate the effects of solution chemistry, galvanic couples, temperature and dynamic flow on the kinetics of pitting under PHTS conditions.

(TTSD; Nuclear Generation; K.W. Lam)

- Localized Corrosion in Decontamination Solutions

Investigations of localized corrosion on the primary heat transport system (PHTS) generated by decontamination solutions will continue in 1986. Both electrochemical and immersion techniques will be used to investigate the conditions under which localized attack will occur.

(TTSD; Nuclear Generation; K.W. Lam)

7.0 OVERVIEW

1985 was characterized by a huge increase in the demands made upon section staff. For example, major short and long term programs were initiated in the Zr corrosion field in direct response to the urgent need for reliable prediction data and analysis to plan future fuel channel maintenance such as REFAB, SLAR and retubing. Fuel Channel materials related concerns having a corrosion association were numerous and included fretting by fuel bundles in Pickering Unit 8, observations of increased deuteriding in Bruce fuel and planning studies requiring future corrosion deuteriding rate predictions. These required a very significant contribution by staff to carry out accelerated and scoping tests and to provide expert consultation and consequently reduced proportionately the effort planned on longer term work. Work in the Heat Exchanger area continued at an increasing rate in 1985, as projected, to deal with replacement material decisions at Pickering and Darlington and, due to competition for resources, this resulted in our inability to undertake planned steam generator tube testing. The largest increase in activities resulted from the combined increasing scope and fixed schedule for TIS work resulting in a quadrupling of staff requirements - a need met by employing temporary contract staff and renting of staff from other divisions. Tritium technology programs related to fusion engineering increased in response to added CFFTP emphasis on building lateral business opportunities. Research in the thermal generation area was maintained at a minimum level to ensure current and future unit reliability and efficiency. A decreasing effort in corrosion studies of irradiated fuel waste container materials resulted from staff resources depleted of capacity to maintain this work, although funding is still available and a greater work scope has been encouraged. New initiatives in the energy utilization field (plasma arc technology) were begun but remained stagnant due to inadequate manpower resources.

The 1986 work program will be dominated by a continuation of key work on Zr corrosion, Heat Exchangers/Steam Generators, and the completion of the TIS project during the first half of the year. Research is already well underway with review status reports in Zr corrosion modelling, Heat Exchanger and Steam Generator studies expected in the first quarter of the year. Additional laboratory space coming on line this year should help increase the capacity for continuation and further development of required Zr corrosion research programs. With the Heat Exchanger programs having been well established during 1985, and now running, more effort will be devoted to defining required Steam Generator research in 1986. The TIS work will be completed before mid 1986 allowing some of these previously committed resources to be applied to bringing the new tritium lab into full operation in the second half of 1986. Asymmetric permeation work, and getter work supported and promoted by CFFTP has established a base of expertise and experimental facilities that will during 1986 generate outputs for evaluation of significant commerical potential as well as direct application now to Darlington TRF operation. The scope of work

planned for the Thermal Generation field, and corrosion studies of nuclear fuel waste containers will remain at a minimum effective level.

Limitations associated with bringing on new staff will continue to result in the need to consolidate program activities to meet the required corporate objectives in the highest priority areas. Concentration on key programs in Zr corrosion, Heat Exchanger/Steam Generator and Tritium technology will dominate section activities in the short term. Medium to longer term plans at this time call for building of even greater depth in each of these concentrated program areas with planned funding from CANDEV, CEA and possibly EPRI, and by initiating increased co-operative research with Universities as well as AECL. Without new staff additions, this could result in our inability to maintain effective programs in other areas.

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